CLAIMS

1. A hollow fiber membrane gas separation apparatus comprising (i) a housing body defined by an essentially cylindrical bowl connected in a sealed and removable manner in correspondence with its axial end portion to a lid, wherein said lid having formed therethrough a feed gas inlet port in a first end of said lid and an outlet product port in a second end of said lid and a gas flow conduit positioned coaxially to said housing body such that said inlet port and said outlet port are spaced essentially in a straight line relative to one another, and said gas flow conduit is placed in fluid communication with said feed gas inlet port or said outlet port, and wherein said bowl being provided with a waste gas exit port placed coaxially to said housing body, and (ii) a substantially cylindrical hollow fiber membrane gas separation cartridge placed coaxially in said housing body and connected in a sealed and removable manner with its first axial end to said gas flow conduit in the lid and with its second axial end to said waste gas outlet port in the bowl said cartridge includes:

(e) an elongated tubular inner core member,

(f) a substantially cylindrical hollow fiber membrane bundle surrounding said inner core member constructed from hollow fiber membranes having permeate and nonpermeate sides, said bundle being characterized as having a substantially countercurrent flow arrangement between the gas flow on said permeate side and the gas flow on said nonpermeate side.

(g) two tubular tubesheets encapsulating both ends of the said hollow fiber bundle in a fluid-tight arrangement with one end of the inner core member opening out of one of the said tubesheets to permit flow of gas in and out of said inner core member and wherein at least one of said tubesheets is severed to permit unobstructed flow of gas in and out of the hollow fiber lumens,

(h) a shell and at least one end closure surrounding said hollow fiber membrane bundle.

2. The apparatus of claim 1 wherein said feed inlet port is in fluid communication with said tubular core member in the hollow fiber membrane cartridge.

3. The apparatus of claim 1 wherein product outlet port is in fluid communication with said tubular core member in the hollow fiber membrane cartridge.

8. The apparatus of claim 1 wherein a portion of the nonpermeate gas stream is used as a sweep gas on the permeate side of the hollow fiber membranes.

9. The apparatus of claim 8 wherein the portion of the nonpermeate gas used as a sweep is controlled by a flow-control orifice.

10. The apparatus of claim 9 wherein said orifice is replaceable.

7. The apparatus of claim 1 wherein said cylindrical bowl is connected to the said lid by a bayonet connection.

8. The apparatus of claim 1 wherein the said waste gas exit port is used to collect a product gas and the said product outlet port is used to remove a waste gas from said apparatus.

13 ~~9~~. The apparatus of claim 1 wherein the feed gas is introduced on the shell side of the hollow fiber membranes in said cartridge and the permeate gas is withdrawn through the hollow fiber lumens.

14 ~~10~~. The apparatus of claim 1 wherein said hollow fiber membranes are wound around said tubular inner core member.

3 ~~11~~. The apparatus of claim 2 wherein the feed gas is introduced internal to said cartridge and the nonpermeate product gas is removed external to said cartridge.

5 ~~12~~. The apparatus of claim 4 wherein the feed gas is introduced externally to said cartridge and the nonpermeate product gas is withdrawn internally to said cartridge.

13. The apparatus of claim 1 wherein said second axial end of the cartridge is connected by a thread to said waste gas outlet port in the bowl.

14. The apparatus of claim 1 wherein connections of said first and second axial ends of the cartridge to said gas flow conduit in the lid and said waste outlet port, respectively, are sealed with o-rings.

15. The apparatus of claim 1 wherein said apparatus is further connected through its feed entrance port to a prefiltration cartridge having a feed gas inlet port and filtered gas outlet port, and wherein said inlet port and outlet ports in said filtration cartridge are spaced essentially in a string line with said feed gas inlet and outlet ports in the gas separation apparatus.

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~~16~~. The apparatus of claim 2 wherein the feed gas is introduced into the lumens of the hollow fibers in said cartridge and the permeate gas is withdrawn on the shell side of the hollow fiber membranes in said cartridge.

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~~17~~. The apparatus of claim ~~16~~ wherein a portion of the nonpermeate gas is used as a sweep on the permeate side of the hollow fiber membranes.

18. The apparatus of claim 1 wherein said hollow fiber membranes are coated along the entire length between the terminal tubesheets except for a narrow region adjacent to one of said tubesheets.

19. The apparatus of claim 1 wherein said hollow fiber membrane bundle is incased with a nonpermeable

wrap except for a narrow gap adjacent to one of said tubesheets.

20. A process for separating at least one gas component in a multicomponent gas mixture from at least one other gas component in said multicomponent gas mixture by bringing said mixture into contact with a first side of the hollow fiber gas separation membranes having a first and a second side, said membranes being assembled in a hollow fiber membrane apparatus of claim 1, permeating a portion of said one gas component to the second side of said hollow fiber membranes and recovering a nonpermeate gas depleted from said one gas component from the first side of said hollow fiber membranes.

21. A gas separation process of claim 20 wherein said gas mixture is air and said one gas component is oxygen.

22. A gas separation process of claim 20 wherein said gas mixture is natural gas and said one gas component is carbon dioxide.

23. A gas separation process of claim 20 further utilizing a fraction of the nonpermeate gas as a sweep on the second side of said hollow fiber membranes.

24. A gas separation process of claim 23 wherein said gas mixture is a compressed air stream or a high pressure natural gas stream and said one gas component is water vapor.

25. A gas separation process of claim 20 wherein said gas mixture is a hydrogen-containing gas stream and said one gas component is hydrogen.

26. A gas separation cartridge comprising:

(f) an elongated tubular inner core member,

(g) a substantially cylindrical hollow fiber membrane bundle surrounding said inner core member constructed from hollow fiber membranes having permeate and nonpermeate sides, said bundle being characterized as having a substantially countercurrent flow arrangement between the gas flow on said permeate side and the gas flow on said nonpermeate side,

(h) two tubular tubesheets encapsulating both ends of the said hollow fiber bundle in a fluid-tight arrangement with one end of the inner core member opening out of one of the said tubesheets to permit flow of gas in and out of said inner core member and wherein at least one of said tubesheets is severed to permit unobstructed flow of gas in and out of the hollow fiber lumens,

(i) a shell and at least one end closure surrounding said hollow fiber membrane bundle,

(j) two connections at the terminal ends of said cartridge containing at least one gas flow channel positioned essentially concentrically to said bundle body, said connections providing a fluid-tight and detachable seal to the axial ends of a substantially cylindrical external housing.

27. The hollow fiber cartridge of claim 26 wherein said hollow fiber membranes are wound around said inner core member.

28. The hollow fiber cartridge of claim 26 wherein the entire exposed length of said hollow fiber bundle between the tubesheets is surrounded by an impervious wrap except for a narrow gap adjacent to one of said tubesheets.

29. The hollow fiber cartridge of claim 26 wherein a flow-control orifice is positioned in said one end closure to allow for a fraction of the nonpermeate gas to be used as a sweep on the permeate side of the membrane.

30. The hollow fiber cartridge of claim 26 wherein a flow-control orifice is placed in one of said tubesheets to allow a fraction of the nonpermeate gas to be used as a sweep on the permeate side of the membrane.

31. The hollow fiber cartridge of claim 26 wherein hollow fiber membranes are coated along with entire length between the tubesheets except for a narrow region adjacent to one of said tubesheets.

32. The hollow fiber cartridge of claim 26 wherein said tubular inner core member is a feed flow gas inlet conduit or a product gas outlet conduit.

33. The hollow fiber cartridge of claim 32 wherein the flow conduit in the tubular inner core member forms the said flow channel in the first or second terminal connection of the cartridge.

34. The hollow fiber cartridge of claim 25 wherein the feed gas is introduced into the lumens of the hollow fiber membranes and permeate gas is collected on the shell side of the hollow fiber membranes.

35. The hollow fiber cartridge of claim 25 wherein the feed gas is introduced on the shell side of the hollow fiber membranes and the permeate gas is withdrawn from the lumens of the hollow fiber membranes.